Use of tracking strips and automatic cameras for detecting Critically Endangered Jerdon's coursers *Rhinoptilus bitorquatus* in scrub jungle in Andhra Pradesh, India

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Abstract Jerdon's courser *Rhinoptilus bitorquatus* is a nocturnal cursorial bird that is now only known from a small area of scrub jungle in Andhra Pradesh, India. Its population size, distribution and habitat requirements are poorly known because of its elusive habits. We conducted a trial of a survey method that involved deploying an array of 5 m long tracking strips consisting of smoothed fine soil, and checking them for footprints at regular intervals. We developed diagnostic methods for distinguishing the footprints of Jerdon's courser from those of other species. Tracks of Jerdon's courser were obtained on about one strip-night in 30 from areas where the species was known to be present. We suggest a procedure for using tracking strips to survey areas where Jerdon's courser has not yet been detected. The use of tracking strips carries a small risk of misidentification of footprints of other species, especially yellow-wattled lapwing *Vanellus malarbaricus*, as those of Jerdon's courser, but has the advantage that large areas can be surveyed without the use of expensive equipment or night-time fieldwork. We recommend the use of automatic camera traps to obtain confirmation of records of probable Jerdon's courser footprints.

Keywords Andhra Pradesh, automatic camera traps, footprints, India, Jerdon's courser, *Rhinoptilus bitorquatus*, tracking strips.

Introduction

Jerdon's courser *Rhinoptilus bitorquatus* (Charadriiformes: Glareolidae) is a small cursorial bird that had not been recorded for more than 80 years until its rediscovery in 1986 (Bhushan, 1986). Since then it has only been seen in a few restricted areas of scrub jungle in Andhra Pradesh, India (BirdLife International, 2001). In the 19th Century the species was also recorded in the Godaveri valley, 600 km away, and may still occur there and in similar habitat elsewhere (BirdLife International, 2001).

Jerdon's courser is categorized as Critically Endangered on the IUCN Red List (Hilton-Taylor, 2000) because it is believed to have a small and declining population, but information on its distribution and population is sparse (BirdLife International, 2001). A systematic survey of the species' distribution would facilitate the assessment of its conservation needs, but Jerdon's courser is difficult to find because it is nocturnal, its calls are not known, and the wooded nature of its habitat and its retiring habits makes visual searches in daylight unproductive. Recent records of Jerdon's coursers have mainly been obtained visually during night-time walks in lightly wooded scrub jungle, during which the observer scans the ground with a torch whilst masking footfalls with an electrical buzzer (Bushan, 1986). On average, Jerdon's coursers are only detected once in several hours of searching, limiting the usefulness of this method. In addition, the efficiency of night-time searching is unknown, making the interpretation of negative results problematical. The assessment of habitat preferences by such surveys may also be unreliable because the method's efficacy seems likely to vary with habitat characteristics, such as the density of bushes and the nature of ground vegetation.

In this paper we propose that tracking strips, which retain imprints of the feet of animals that walk over them, should be used in surveys of the distribution of Jerdon's courser, with species identity being confirmed by night-time searches or automatic cameras in areas where tracking indicates that the species is present. The technique also has potential for surveying and quantifying habitat use of other ground-living birds that

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are difficult to survey. Tracking methods have often been used in surveys of mammals, but have rarely been applied to birds (Sutherland, 1996).

Study area

The study was conducted in scrub jungle in the Sri Lankamaleswara Wildlife Sanctuary, near Reddipalle, Cuddapah District, Andhra Pradesh, India (14°N 79°E). Automatic cameras and tracking strips were placed in two areas of open scrub, surrounded by denser shrubs and trees, where Jerdon's coursers had previously been seen by P.J., A.R. and K.N. The two patches, JC1 and JC2, were 1.5 ha and 2.0 ha respectively and were 80 m apart at their nearest. Tracking strips were also placed in selected open areas of pasture and crop land outside the reserve where other bird species were observed, so that their footprints could be obtained for comparison with those of Jerdon's courser.

Methods

Tracking strips

Fine loess soil was collected near the reserve and passed through a 1 mm sieve. Particle size analysis of a sample of the sieved soil, using a Mastersizer (Malvern Instruments Ltd, Malvern, UK), showed that 50% of its volume was composed of particles <27 μm in diameter. Soil and sand with larger particles did not retain clear imprints, especially when dry. A strip of ground 5 m long and 25 cm wide was cleared of stones and its sparse covering of dried-out grasses. The sieved soil was spread along the strip, flattened into a layer 1–2 cm thick, slightly compacted and then smoothed with a builder's trowel. A thin layer of soil, collected adjacent to the strip, was dusted onto the surface with a sieve so that any tendency for birds to be deterred from walking on it by its smooth surface or slight difference in colour from the adjacent soil would be reduced. Each strip required *c.* 25 kg of soil. Ten tracking strips were deployed in JC1 and eight in JC2 between 30 January and 7 March 2001. A distance of 24–72 m was maintained between each strip and its nearest neighbour, and positions were recorded using a Global Positioning System (Garmin GPS III).

Checking of tracking strips and recording of footprints

Tracking strips in JC1 and JC2 were checked at intervals of 1–4 days, but usually on alternate days, for total periods of 27–54 days up to 8 April 2001. Checks of simulated bird footprints showed that they remained in good condition for at least 8 days provided there was no rain. Tracks of birds were recorded, and photographs taken from directly above and/or plaster of Paris casts were taken of samples of those tracks that were close to the size expected for Jerdon's courser. Each visit to a strip on which tracks were recorded is termed a tracking event, regardless of the number of footprints or their distribution on the strip. Occasionally it was noted that footprints had been obscured by strong wind, rainfall or disturbance by humans or livestock, and the period between such a visit and the previous one was therefore excluded from further analysis. After each visit, the surface of a strip was smoothed.

In addition to collecting plaster casts and photographs of footprints from the tracking strips deployed in JC1 and JC2, we also did so from strips at other sites, including pasture and crop land near the reserve. These sites were selected because they were frequented by species whose footprints may be confused with those of Jerdon's courser and could be watched during daytime. We were thus able to obtain footprints that were known to have been made by particular species. We also used automatic cameras to identify the species leaving footprints at some of these sites.

Footprints were measured on plaster casts and on photographs. Straight lines running along the central long axis of the imprints of each of the three toes were marked on the cast or photograph and the distances between the intersection of these lines at the hind margin of the foot (B) and points at the tips of the outer (O), central (C) and inner (I) toes were measured with vernier callipers to give distances BO, BC, BI respectively. For photographs the distances were calibrated by measuring a scale marked in mm, that was included in the photograph. The intersection point B coincides approximately with the hind margin of the foot. Using the intersection rather than the hind margin itself allowed the measurement of footprints of running birds, which often do not leave a full imprint of the hind part of the foot. The distances between the tips of the outer and central (OC) and inner and central (IC) toes were also measured. The angle between the long axes of the outer and central toes was then calculated as $\arccos((BC^2 + BO^2 - OC^2)/(2{*}BC{*}BO))$ and the equivalent angle for the inner and central toes as $\arccos((BC^2 + BI^2 - IC^2)/(2{*}BC{*}BI))$. The angle between the outer and inner toes was the sum of these two angles. Where we had measurements of more than one footprint from a given tracking event, we took means of these measurements for use in further analyses.

Automatic cameras

Eight Trailmaster camera kits (Goodson & Associates Inc., 10614 Widmer, Lenexa KS 66215, USA) were used, each of which consisted of a TM1500 infra-red transmitter

and receiver/logger, a TM35-1 camera, and connecting cable. Cameras were deployed at eight sites in JC1 and seven in JC2 between 29 January and 15 February 2001. At each site a 5–6 m long strip was monitored, some of which were tracking strips. People collected wood and grazed buffalo during daytime, so the equipment was hidden in bushes or deployed at dusk and removed at dawn.

The camera, transmitter and receiver/logger were either installed at the base of a bush or on wooden stakes driven into the ground so that the infra-red beam would pass *c.* 12 cm above the ground. The camera was mounted in a protective shield at a height of about 70 cm and set to look along the line of the beam. Camera shields and units were camouflaged with patterns of black and brown.

The locations of cameras were recorded with a GPS, removing the need for visible markers. The receiver/logger was programmed only to trigger the camera between dusk (18.30) and dawn (06.30), only if the beam was broken for at least 0.05 seconds, and not to take another photograph if the beam was broken again within one minute.

Plate 1 Automatic flash photograph of a Jerdon's courser triggered when the bird broke an infra-red beam at 00.24 on 14 February 2001. The bird is leaving footprints across a tracking strip (a 25 cm wide, 5 m long strip of fine soil placed between the transmitting and receiving units of the triggering device).

Measurements of museum skins

Skins of species whose footprints may be mistaken for those of Jerdon's courser were examined in the University Museum of Zoology, Cambridge, UK and two skins of Jerdon's coursers were examined, one in Cambridge and one at the museum of the Bombay Natural History Society in Mumbai, India. Measurements were made, with dial callipers, of the distance between the hind margin of the foot and the tip of each of the three main toes (excluding the claw). Where toes had curved during drying, a piece of soft plastic-covered wire was bent to match the shape of the toe and the two end-points were marked on the wire, which was then straightened and the distance between the marks measured. The left foot was measured unless its toes were more curved than those of the right foot.

Results

Automatic cameras

Excluding a few nights on which the triggering devices malfunctioned, the cameras operated for 42 camera-nights (22 in JC1 and 20 in JC2). Four photographs of birds were obtained, two of Jerdon's courser (at two sites in JC1; Plate 1), one of stone-curlew *Burhinus oedicnemus* and one of red-wattled lapwing *Vanellus indicus*. Hence, the estimated probability per camera-night of obtaining a photograph of Jerdon's courser in the two areas combined was $2/42 = 0.0476$. The exact binomial 95% confidence limits (Diem, 1962) of this estimate were 0.0060 to 0.1616. Stone-curlews and red-wattled lapwings were also seen in both of the areas of scrub jungle and their calls were frequently heard, but no other charadriiform species were seen on the ground.

Identification of footprints on tracking strips

Before beginning the study we compiled a list of bird species known or believed to occur in or near the study area, and assessed the possibility that each species may have footprints that could be confused with those of Jerdon's courser. Because Jerdon's courser lacks a hind toe, we first eliminated all species with a hind toe sufficiently large to leave an imprint. We then used measurements of the length of the central toe of museum skins to eliminate species whose footprints would be too small or too large to be confused with those of Jerdon's courser. Comparison of mean toe lengths of museum specimens with those from plaster casts of footprints of the same species showed that they were similar to within 2 mm, so measurements of museum specimens were used as a rough guide to species whose footprints could be confused with those of Jerdon's courser. As the central toe lengths (BC) of two museum specimens of Jerdon's courser were 28.0 and 26.3 mm, we developed diagnostic methods to distinguish footprints from those of other species with mean central toe lengths of 20–40 mm, which were painted sandgrouse

Pterocles indicus, chestnut-bellied sandgrouse *Pterocles exustus*, Indian courser *Cursorius cormandelicus*, yellow-wattled lapwing *Vanellus malarbaricus*, red-wattled lapwing, stone-curlew and barred buttonquail *Turnix suscitator*.

For most of these species we were able to restrict further diagnostic analysis to measurements from casts and photographs of footprints of known origin made on tracking strips (Table 1), but we did not obtain enough measurements to do this for the two sandgrouse species. Examination of the feet of museum skins of painted and chestnut-bellied sandgrouse showed that both had larger pads at the hind margin of the foot than Jerdon's courser and other Charadriiformes. One set of tracks of chestnut-bellied sandgrouse, obtained on a tracking strip placed in an area to which this species was attracted using grain as bait, also showed impressions of these pads, which, when visible at all on the footprints in two Jerdon's courser tracking events confirmed by the automatic cameras, were shorter (3–4 mm) than those of the sandgrouse (7–10 mm). Hence, we believe that tracks of the two sandgrouse species can probably be separated from those of Jerdon's courser on this criterion, though further support for this conclusion is needed from measurements of larger samples of tracks.

Table 1 shows means of measurements from photographs and plaster casts of footprints from tracking strips laid in areas selected so that tracks attributable to particular species could be obtained. All species with footprints that could be confused with those of Jerdon's courser are included, other than the sandgrouse. We also present measurements of footprints from two tracking events of Jerdon's courser in which the origin of the track was confirmed by automatic camera photographs (Plates 1 & 2). Mean measurements of 15 other tracking events attributed to Jerdon's courser by their resemblance to the tracks obtained on the camera-monitored strips are also shown.

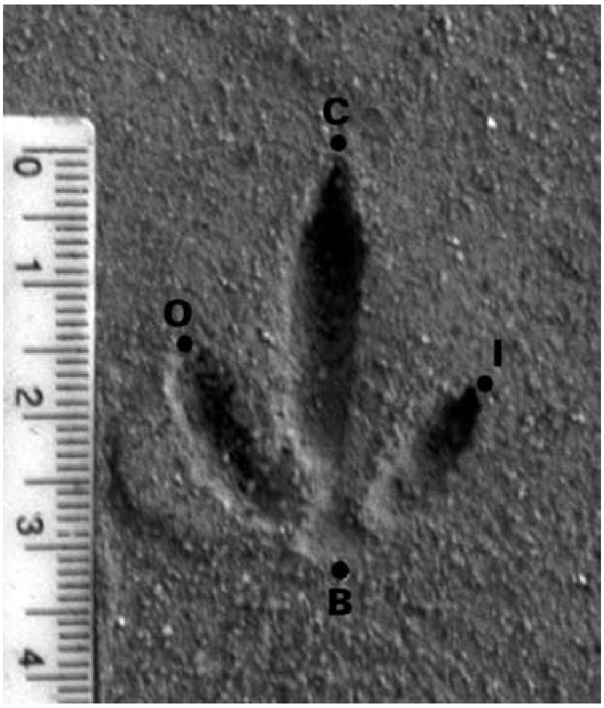

Plate 2 Footprint of a Jerdon's courser on a tracking strip from the tracking event shown in Plate 1. The scale is graduated in mm. The labels O, C, I and B mark the tips of the outer, central and inner toes and the hind margin of the foot respectively.

Footprints of barred buttonquail were smaller than those of Jerdon's courser, whilst those of stone-curlew and red-wattled lapwing were larger (Table 1). The central toe lengths of full-grown birds of these species are likely to overlap those of Jerdon's courser only rarely.

Table 1 Means of linear measurements (mm), toe length ratios and angles between toes (degrees) from footprints of Jerdon's courser and other cursorial bird species. Sample size (*n*) is the number of tracking events. Means were taken where more than one footprint was measured from the same tracking event.

Species	Central toe		Outer toe		Inner toe		Ratio O:C		Ratio I:C		Angle O-C		Angle I-C		Angle O-I		*n*
	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	
Jerdon's courser[1]	29.4	–	19.0	–	16.4	–	0.646	–	0.558	–	35.9	–	39.8	–	75.7	–	1
Jerdon's courser[2]	–	–	–	–	–	–	0.657	–	0.604	–	40.1	–	40.2	–	80.3	–	1
Jerdon's courser[3]	28.27	1.91	20.03	1.73	18.42	1.27	0.712	0.057	0.657	0.038	36.1	2.9	40.5	4.3	76.6	5.9	15
Indian courser	28.71	1.93	16.86	1.66	14.56	1.73	0.587	0.033	0.506	0.041	43.6	7.5	52.5	7.7	96.1	4.7	18
Yellow-wattled lapwing	28.97	1.68	21.08	1.39	17.48	0.95	0.728	0.034	0.604	0.024	46.2	7.0	51.4	4.4	97.6	9.5	14
Red-wattled lapwing	37.72	1.02	29.05	0.91	24.15	1.18	0.771	0.034	0.641	0.033	48.8	5.2	50.8	7.1	99.5	9.3	17
Stone-curlew	39.44	1.52	29.89	1.88	24.90	2.32	0.758	0.031	0.630	0.042	31.9	6.3	25.5	2.9	57.3	7.2	12
Barred buttonquail	23.34	0.85	18.83	1.05	14.65	0.80	0.807	0.027	0.628	0.018	42.4	0.8	42.7	1.9	85.1	2.7	6

[1]From a 35 mm transparency of two footprints made by a Jerdon's courser photographed crossing a tracking strip on 14 February 2001.
[2]From a colour print photograph of two footprints made by a Jerdon's courser photographed crossing a tracking strip on 14 February 2001. A scale was not present in this photograph, so absolute measurements of toe length could not be calculated.
[3]From plaster casts, 35 mm slides and photographs of tracking events attributed to Jerdon's courser on the basis of resemblance to the events labelled 1 and 2 in this Table. A scale was not included in photographs, so toe lengths are based upon $n = 13$.

The angle between the outer and inner toes was larger for Indian courser, and red-wattled and yellow-wattled lapwing than for Jerdon's courser, whilst this angle was smaller for stone-curlew than for Jerdon's courser (Table 1, Figure 1). The outer and inner toes of Indian courser also tended to be shorter, relative to the central toe, than those of Jerdon's courser (Table 1).

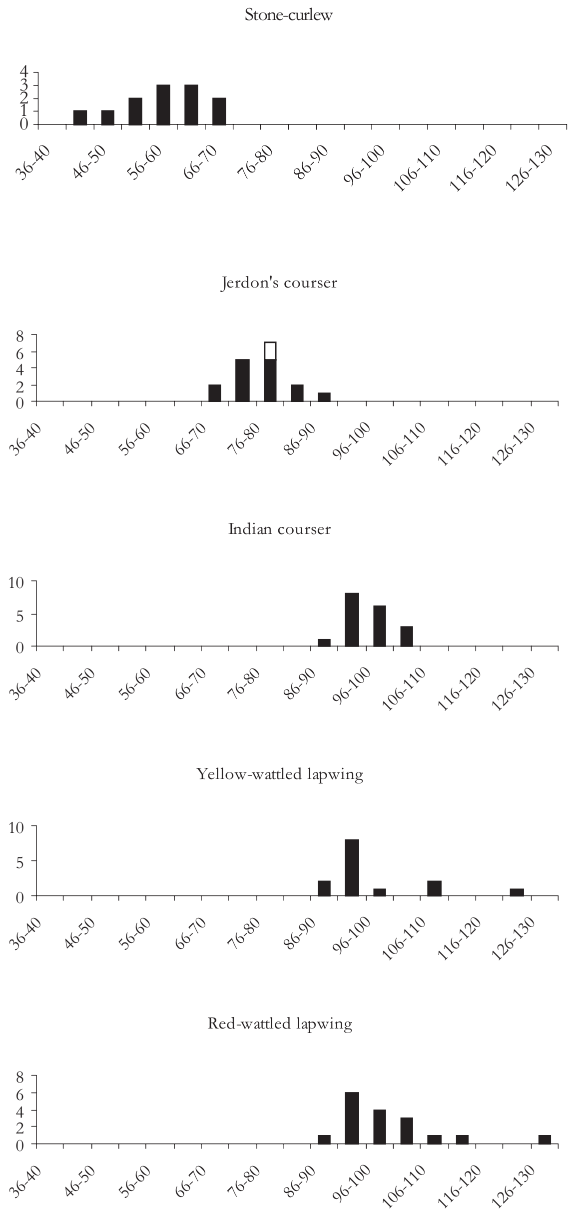

Fig. 1 Frequency distributions of mean angles between the outer and inner toes from plaster casts and photographs of footprints of five bird species, in 5° bins. For Jerdon's courser, two tracking events for which the species identity was confirmed by automatic camera photographs are shown separately (white bar) from 15 events classified as Jerdon's courser by resemblance to the confirmed tracks (black bars).

We conclude that most tracking events of Jerdon's courser can be distinguished from those of other species on the basis of size, the length of the toes relative to one another, and the angle between the outer and inner toes. The last character alone is likely to be sufficient to distinguish tracks made by partly-grown precocial young of stone-curlew and red-wattled lapwing from those of full-grown Jerdon's coursers, even when they are not distinguishable by size. We measured plaster casts of footprints from one tracking event (not included in Table 1) in which a partly grown chick of red-wattled lapwing was observed to cross a tracking strip. The mean length of the central toe was 29.0 mm, much less than that of full-grown birds of the same species and similar to Jerdon's courser (Table 1). However the mean angle between the outer and inner toes was 108.6°, which is well within the range for full-grown red-wattled lapwings and considerably larger than for Jerdon's courser.

There is some overlap between Jerdon's courser and other species in the angle between the outer and inner toes, so tracks of species such as yellow-wattled lapwing would be expected to occasionally be misidentified as those of Jerdon's courser. The error rate depends upon the relative abundance of the species in the habitats selected for survey.

Tracking events

Footprints of three charadriiform species, Jerdon's courser, stone-curlew and red-wattled lapwing, were observed on the tracking strips set in the two study areas where Jerdon's courser had previously been seen (Table 2). The estimated probability per strip-night of obtaining a tracking event of Jerdon's courser in the two areas combined was $24/781 = 0.0307$. The exact binomial 95% confidence limits of this estimate were 0.0193 to 0.0429.

Table 2 Numbers of tracking events attributed to Jerdon's courser, stone-curlew and red-wattled lapwing on 18 tracking strips set during 31 January–8 April 2001 in two areas (JC1 and JC2) where Jerdon's courser was known to occur. Numbers of strip-nights monitored and estimated probabilities per strip-night of observing a tracking event are also given.

Species	Site	Strip-nights	Tracking events	Events per strip-night
Jerdon's courser	JC1	420	17	0.04048
	JC 2	361	7	0.01939
	Both	781	24	0.03073
Stone-curlew	JC 1	420	53	0.12619
	JC 2	361	35	0.09695
	Both	781	88	0.11268
Red-wattled lapwing	JC 1	420	32	0.07619
	JC 2	361	28	0.07756
	Both	781	60	0.07682

Tracking events attributed to Jerdon's courser were recorded on 11 of the 18 tracking strips, with a maximum of four events occurring on the same strip. Expected probabilities of observing 0, 1, 2, etc tracking events were calculated for each strip by using the Poisson theorem and assuming that the expected mean number of tracking events for the strip was the product of the estimated probability of a tracking event per strip-night, calculated over all strips (0.0307), and the number of nights for which the strip was monitored. These probabilities were then summed to give expected numbers of strips at which 0, 1, 2, etc tracking events would be observed. The expected numbers of strips with 0, 1, 2, 3, 4 and 5 or more tracking events were 5.07, 6.08, 3.99, 1.88, 0.70 and 0.28 respectively compared with the observed distribution of 7, 5, 1, 3, 2 and 0. The observed and expected distributions are similar and are not significantly different ($\chi_{(2)} = 1.03$, $P > 0.25$; strips with two or more tracking events combined to avoid expected cell totals <5). Hence, our observations are consistent with the hypothesis that the underlying probability of Jerdon's courser leaving tracks was similar for all the tracking strips in our scrub jungle study areas.

Discussion

This study shows that the presence of Jerdon's courser in an area of scrub jungle can be detected both by automatic cameras and by tracking strips and that the probabilities of detecting Jerdon's courser per night of monitoring with a single camera or a single strip were similar (0.0476 cf. 0.0307 respectively). Therefore, both methods may have applications in surveys of the distribution of Jerdon's courser. An important function of such a survey would be to provide firm evidence of not only the presence, but also the absence of the species from a given area. Hence, it is necessary to consider the reliability of a survey with cameras or tracking strips that suggested that Jerdon's courser was absent because no records had been obtained. Suppose that we wish there to be probability V of being incorrect if we regard Jerdon's coursers as being absent from a patch of potentially suitable habitat where we have obtained no photographs or tracking events in a survey consisting of K camera-nights or strip-nights of monitoring. Assume also that we have an estimate R of the nightly probability of obtaining a photograph or tracking event in areas where Jerdon's coursers are present and that this applies equally to all cameras or strips. It can be shown that, under these circumstances, the target error rate V will be obtained if

$$V = (1 - R)^K.$$

Rearranging this to obtain an expression for K gives

$$K = \log(V)/\log(1 - R).$$

Hence, if we wish a survey to have a 1% chance of being wrong in suggesting that Jerdon's courser is absent from an area in which no records are obtained and use the estimate of R from the tracking strip survey (0.0307), we obtain the required number of camera-nights or strip-nights as

$$K = \log(0.01)/\log(1 - 0.0307) = 148.$$

It must be borne in mind that our value of R is an estimate from limited data, and that the true value obtained by carrying out a survey with many more strip-nights may be somewhat lower. It is also the case that our estimate of R comes from just two small patches of habitat, and that the density or activity of Jerdon's coursers may well be lower in other patches. Therefore it is prudent to use a considerably lower value of R for this calculation, so we arbitrarily take the value $R = 0.01$. This then gives

$$K = \log(0.01)/\log(1 - 0.01) = 458.$$

We conclude that if we were to survey an area using more than 458 camera-nights or strip-nights then there would be a chance of 1% or less of being incorrect in taking an absence of Jerdon's courser records to indicate that the species was absent during the survey. This calculation will only be valid if there is a high probability that the home range of any Jerdon's courser present in a survey area overlaps several camera or tracking strip sites. Hence, the sites should not be spaced too far apart and should be placed on an approximately regular grid. In the absence of any information on the ranging behaviour of Jerdon's courser we assume from experience of other charadriiforms (e.g. Green *et al*., 2000) that the spacing of tracking strips used in this study (an average of about 50 m) would be adequate. A practical method for surveying a 5 ha patch of apparently suitable habitat would therefore be to place 20 cameras or tracking strips on a grid at regular intervals of 50 m and to monitor them for at least 23 nights.

These calculations indicate that it would be difficult to accomplish a large-scale systematic survey of Jerdon's courser distribution using cameras alone. Not only are the camera kits costly, but in areas frequently visited by people and livestock it would probably be necessary to remove and redeploy the equipment at dawn and dusk every day. The effort involved in this limited the extent to which we used cameras in our study. We suggest that a more practical procedure would be to use tracking strips for the survey. This has several advantages. The material for the strips is freely available. Although the effort to prepare the soil and deploy the strips is

considerable, it is similar to that involved in installing cameras. We found that two people could deploy 8–10 cameras or strips in a day, given that the study area could be approached to within 100 m in a vehicle. The strips can be checked quickly and it would probably be acceptable to extend the interval between checks to at least five days. The method is most suitable for areas similar to our study area that have a long dry season; heavy rain washes the fine soil away and necessitates the replacement of strips.

The use of tracking strips has the disadvantage that there is a small but definite risk of misidentifying footprints, whereas automatic camera photographs taken at a range of less than 5 m would nearly always allow species to be identified with certainty. To overcome this problem, we recommend that a large-scale survey should be carried out using tracking strips, but that in any areas in which tracking events are attributed to Jerdon's courser, automatic cameras should be deployed as soon as possible to confirm the identification.

At present we think that a survey using tracking strips offers the best prospect of obtaining accurate information on the range of this species. Surveys that involve listening for calls or eliciting them by playing tape recordings of conspecifics may be superior, and efforts are being made to identify and record the calls of Jerdon's courser, which are little known (BirdLife International, 2001).

The method could not be used in its present form to estimate the size of the population of Jerdon's courser, but it has been shown that the crude rate at which tigers *Panthera tigris* trigger automatic camera traps is closely correlated with their population density (Carbone *et al.*, 2001). It may be that an equivalent calibration could be obtained for the rate at which tracking strips are crossed by Jerdon's coursers. Tracking strips may also have useful applications in other aspects of the study of Jerdon's courser and other cursorial birds, such as the quantification of habitat and microhabitat use and selection.

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